REMARKS

Claims 1-26, all the claims currently pending in the application, stand rejected on prior art grounds. Claims 1, 8, 10, 12, 19, and 20 are amended herein. The Applicant respectfully traverses these rejections based on the following discussion.

I. The Prior Art Rejections

Claims 1-26 stand rejected under 35 U.S.C. §102(e) as being anticipated by Su (U.S. Patent No. 6,388,253). The Applicant respectfully traverses these rejections based on the following discussion.

Su teaches a method and apparatus for reducing lot to lot CD variation in semiconductor wafer processing feeds back information gathered during inspection of a wafer, such as after photoresist application, exposure and development, to upcoming lots that will be going through the photolithography process, and feeds forward information to adjust the next process the inspected wafer will undergo (e.g., the etch process). Su further teaches forming a feature such as an etch mask on a semiconductor wafer at a "photo cell" by a photolithography process, then conventionally imaging the feature with a CD-SEM to measure its CD and other sensitive parameters. The measured parameters are linked, via the feature's SEM waveform, to photolithography adjustable parameters such as stepper focus and exposure settings. If the measured parameters deviate from design dimensions, the linked information on focus and exposure is fed back to the photo cell so the stepper can be adjusted, either automatically or at the user's discretion, to correct the deviation in following lots. The measured parameters are also linked to etch process adjustable parameters such as etch recipes for different over-etch and/or etch chemistry. If the measured parameters deviate from desired values, a linked etch recipe to

correct the error is fed forward to the etcher and implemented automatically or at the user's discretion. This feedback and feed-forward mechanism improves lot to lot CD control at inspection following photoresist development and at final inspection as well.

However, the claimed invention, as provided in amended independent claims 1, 8, 10, 12, 19, and 20 contain features, which are patentably distinguishable from the prior art reference of record. Specifically, claims 1 and 8 generally provide, in part, "...calibrating said image data by determining at least three best fit data parameters for improving a linearity of said image data... wherein said optimum critical dimension value comprises structural measurements of said critical dimension structure that are only relevant to a critical dimension of said critical dimension structure." Similarly, claim 10 generally provides, in part, "calibrating said image data by determining at least three best fit data parameters for improving a linearity of said image data ... wherein said optimum critical dimension value comprises structural measurements of a critical dimension structure that are only relevant to a critical dimension of said critical dimension structure." Likewise, claims 12, 19, and 20 generally provide, in part, "...calibrating said data by determining at least three best fit data parameters for improving a linearity of said data... wherein said optimum critical dimension value comprises structural measurements of said critical dimension structure that are only relevant to a critical dimension of said critical dimension structure." Su teaches none of these features.

Applicant's claimed invention teaches combining a stepper focus parameter with an approximate critical dimension (CD) measurement and (at least three) best fit data parameters. Conversely, nowhere in Su is it taught that an optimum CD value can be generated by combining stepper focus with an approximate (i.e., less than optimum) CD value and at least three best fit parameters used to improve the linearity of the CD data. In fact, combining the stepper focus

with CD data as suggested and implemented by Su will not achieve optimum CD values. This is because Su assumes that the CD value is already optimal. However, in fact, it is not optimal, as experimental results indicate. According to column 3, lines 52-57 through column 4, lines 1-11 of Su, CD measurements are taken and are compared with design dimensions. If there is a deviation between the CD measurements and the established design dimensions, then Su corrects the deviation by adjusting the stepper dose. Thus, in Su no changes or adjustments are made to the critical dimension measurement (i.e., no improvement (optimization) is made to the critical dimension measurement). Conversely, in the claimed invention an improvement (optimization) is made to the critical dimension measurement by combining the stepper focus parameter with the critical dimension measurement. In other words, Su changes the stepper dose parameter to reduce the deviation of measured parameters from design dimensions to achieve process control rather than combining the stepper focus parameter with the CD measurement to generate an improved CD measurement. As such, these (claimed invention compared with Su) are two fundamentally distinct inventions.

Pages 2 through 4 of the Office Action states that Su discloses "obtaining a focus exposure matrix..." and "performing an analysis of the data to generate a 'golden waveform'." However, the Applicant's claimed invention claims no such features. Thus, the Applicant is unclear as to the correlation that the Office Action is attempting to be made between these features and the Applicant's claimed invention.

Generally, Su (1) uses a reference CD value (which it assumes is optimal, when in fact it is not optimal); (2) measures a CD value; (3) compares the reference CD value to the measured CD value; and performs an etch process according to the difference in the reference CD value and the measured CD value. Conversely, the claimed invention is basically challenging the

validity of the reference CD in Su, which is taken as an optimum value. As such, the claimed invention provides an analytical approach of optimizing the CD value by using best fit parameters to improve the linearity of the approximate CD data (i.e., reference CD data).

There exist many other fundamental differences and patentable distinctions between the claimed invention and the teachings of Su as well. Specifically, Su teaches how to control a lithography manufacturing process by using SEM (scanning electron microscope) waveform information and SEM CD (critical dimension) measurement to provide feedback and feedforward to dynamically tune lithography and etch processes. Conversely, the claimed invention provides how to make a significantly more accurate CD measurement by correcting the initial (old) CD measurement by using lithography-defocus-sensitive information either from the CD or from some other source and combining this with the best fit data parameters in an analytical as discussed above. Additionally, what distinguishes the claimed invention from the Su is the understanding that CD measurements inherent in Su are essentially corrupted due to consideration of structural characteristics, which are not relevant to the critical dimension, but which are highly sensitive to the stepper focus, such as sidewall angle, edge width, and profile grade (as clearly indicated in column 3, line 60 of Su).

As the Applicant has previously stated, common to the patent of Su and the claimed invention is a body of work referenced in both, which teach that the printed feature has profile properties that can be sensitive to both lithography tool dose and focus settings. In some cases of the prior art, specialized targets are described that are particularly sensitive to defocus; i.e., measurements by optical or electron beam based tools provide defocus determination with much smaller uncertainty than what can be determined by using the waveform and CD from SEM measurement at a critical control feature. The work of Davidson et al. and Villarrubia et al.

(referred to the Applicant's specification, page 7, lines 4-12) study the possibility of extracting printed structure profile information from the full SEM waveform. As Archie et al. (U.S. Patent 5,969,273 have taught, the sidewall information from the SEM waveform is a sensitive indicator of lithography tool defocus.

Su uses this prior art to teach a possible method for extracting stepper focus and dose information, as well as sidewall information, from the SEM waveform for the purpose of providing corrective actions in manufacturing processes. <u>However, and most significantly, Su does not teach how to improve (optimize) upon the critical dimension measurement itself as does the claimed invention.</u>

Achieving a more accurate CD measurement is an important application of the CD-SEM that is outside of the manufacturing control application. In particular, there are three main uses for the CD-SEM:

1. Process development, including lithography process development;
2. Manufacturing process control; and
3. Diagnostic measurements for an Out Of Control (OOC) manufacturing process.

Su clearly addresses only the second application (2) above. In that application where many manufacturing processes have been previously optimized and fixed, the dominant process variables that vary under normal circumstances act like stepper dose and focus variations. Only under these conditions is the process control method taught by Su a possible control strategy. Conversely, the claimed invention addresses the other two applications (1 and 3 above) for the CD-SEM as well as providing a more accurate CD measurement for dispositioning of a product.

During process development many more process and design parameters can vary and highly accurate CD measurements are needed to understand the issues. This situation continues

to worsen as lithography and etch processes evolve to produce ever smaller features. One example that has gained importance in recent years is the need to make accurate CD measurements of a variety of structure geometries at a variety of design sizes in order to develop accurate simulation models of the full lithography process. With an accurate simulation model, the chip design data can be modified (optical proximity corrections, sub-resolution assist features, phase shifting technology for the mask, etc.) to improve upon the printing fidelity (printed image versus pre-OPC (optical proximity correction) design data).

To make accurate critical dimension measurements to feed into the simulation model optimization or verification, the measurements must not be corrupted by secondary characteristic changes in the critical shape being measured. In particular, profile changes caused by lithography focus-like variations should not be allowed to alter the base CD measurement. As such, the claimed invention removes the profile-change-induced-errors in the measurement thereby revealing the design-induced-changes needed for simulation optimization or verification. This is accomplished by combining the stepper focus with a critical dimension measurement, which generates an optimum critical dimension. It is noteworthy that this use of the CD-SEM continues to grow as the industry starts to move away from CD-SEM as the principal tool for manufacturing control (application 2) toward scatterometry as the preferred metrology system for control.

Generally, the claimed invention teaches a method to improve and optimize the accuracy of the CD-SEM measurement that relies on either additional information in the waveform or other information coming from another distinct CD-SEM measurement or from another distinct non-CD-SEM measurement.

Conversely, Su assumes that the basic CD-SEM CD measurement is adequate for process

control and thus forms the basis for process control. As such, Su does not seek to improve or optimize the CD value. Furthermore, Su tends to focus on how to directly determine stepper focus and dose conditions by directly comparing target waveform to reference waveforms. As such, Su does not explicitly teach how to use additional waveform information to obtain a more accurate CD measurement.

It appears that the Office Action is contending that Su teaches all of the elements of how to make a more accurate CD measurement. However, since Su's purpose is solely to teach process control and more precisely, a method to obtain more control of the final etch CD, Su does not describe how to make a more accurate CD measurement. Furthermore, Su teaches how to obtain a set of reference data by constructing reference data (CD, waveforms, and other data (see Figure 2B of Su) from specially constructed Focus-Exposure-Matrix wafers (see Figure 1 of Su). However, attempting to match a target waveform to one of the reference waveforms and then reporting a CD result based on that match would provide too coarse a CD measurement, thereby teaching away from the claimed invention's method of producing an optimum CD value. Experimental testing as conducted by the Applicant, with the results provided and described in Applicant's Figures 2, 9, and 10 and associated text in the specification indicate that there are many problems with this type of prior art approach including the impracticality of constructing a large enough FEM wafer to reduce the coarseness and the issue how to exactly distinguish between similar reference waveforms.

Furthermore, the Applicant's specification further teaches that SEM resolution is a critical issue today and will only get worse in the future. Moreover, many details of the feature affect the critical portions of the waveform (see Figures 6A-6C of Su) including the bottom CD and many elements of the sidewall profile. Waveforms can differ because of changes in many of

the feature properties but Su fails to teach how to weigh this information to extract the CD free of the secondary characteristics of the profile.

As such, the claimed invention relies on the sophisticated CD methodologies already available on commercial CD-SEMs. These methodologies have been developed to overcome noise limitations in the waveform as well as to seek the bottom edge signature in the waveform. The claimed invention's approach is to provide a correction to that determination based on additional information possibly coming from analyzing the waveform in another way to gain stepper focus like information or if necessary using information from a separate measurement. As such, the claimed invention's approach does not suffer from either the coarseness problem or the resolution-limiting-convolution of multiple feature signatures in the waveform.

In view of the foregoing, the Applicant respectfully submits that the cited prior art reference, Su, does not teach or suggest the features defined by amended independent claims 1, 8, 10, 12, 19, and 20 and as such, claims 1, 8, 10, 12, 19, and 20 are patentable over Su. Further, dependent claims 2-7, 9, 11, 13-18, and 21-26 are similarly patentable over Su, not only by virtue of their dependency from patentable independent claims, respectively, but also by virtue of the additional features of the invention they define. Moreover, the Applicants note that all claims are properly supported in the specification and accompanying drawings. Thus, the Applicant respectfully requests that these rejections be reconsidered and withdrawn.

II. Formal Matters and Conclusion

With respect to the rejections to the claims, the claims have been amended, above, to overcome these rejections. In view of the foregoing, the Examiner is respectfully requested to reconsider and withdraw the rejections to the claims.

In view of the foregoing, Applicants submit that claims 1-26, all the claims presently pending in the application, are patentably distinct from the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary. Please charge any deficiencies and credit any overpayments to Attorney's Deposit Account Number 09-0458.

Respectfully submitted,

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